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Effect of Parboiling and Related Treatments on the Milling, Nutritional, and Cooking Quality of Rice

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THE effect of modern milling methods in lowering the vitamin B_1 (thiamine) content and nutritional value of raw rice has been emphasized in this country and in Asia in recent years. As rice leaves the thresher, the kernel is enclosed in a hull, or husk. It is then known as rough rice, or paddy. Rough rice is used for seed and at times for feed, but the hulls must be removed before the grain is suitable for human food. Rice with the hulls removed is known as brown (or husked) rice; after the removal of part of the bran layers and germ, it is known as undermilled (or unpolished) rice; and when practically all of the bran layers and germ are removed, it is known as milled rice. Brown rice contains more protein, minerals, and vitamins than milled rice, but on the other hand it is reported in the Orient to cause digestive disturbances. Milled rice is more attractive in appearance, requires less time to cook, and keeps better in storage than brown and undermilled rice. Furthermore, in hot humid climates, in which most of the world's rice crop is produced and consumed, both brown and undermilled rice soon become rancid.

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The milling process has long been known to remove much of the vitamin and mineral content in the grain, and in certain areas in Asia premilling treatments of rough rice have been devised to improve its milling, nutritional, and keeping qualities. Rice not pretreated is referred to in this circular as raw rice. Both raw and pretreated milled rice must, of course, be cooked before serving. In much of Asia, rice is the "staff of life," and where the annual per capita consumption of milled raw rice is high and the diet is not properly supplemented with other protective foods, the deficiency disease beriberi often occurs.

Considerable interest in treating rough rice has recently developed in this country, and a rice-conversion plant began operating in Houston, Tex., in 1942. The "conversion process" is a modified method of parboiling, i. e., soaking, steaming, and drying, and the milled product is known commercially as "converted rice." Rice is also being parboiled by a modified method in California. Converted and parboiled rice are classified and graded as Parboiled rice under the United States Standards for Milled Rice (i. e., Parboiled light, Parboiled, or Parboiled dark, depending on its degree of discoloration).

The study here reported was undertaken to determine the effect of various premilling treatments on milling quality and thiamine (vitamin B_1) content of raw and treated rice from which varying quantities of the bran had been removed by milling to different degrees. It may be summarized as follows:

SUMMARY

Three varieties of rice grown under like conditions in Texas in 1943 were pretreated before milling by 12 different methods, and the effect of the treatments on milling quality, thiamine content, and cooking and canning qualities was determined.

The average increase in head rice yield in the three varieties was 8 percent for the siddha, sela, and josh treatments, and 26 percent for the eight parboiling treatments.

The highly milled samples of the siddha, sela, and josh treatments retained 5 times as much thiamine as the raw lots milled to the same degree; those of four parboiling treatments, 4.5 times as much; and those of two parboiling treatments, 3.7 times as much. The addition of a small quantity of thiamine hydrochloride to the water in which the rough rice was soaked increased the thiamine content of the parboiled milled rice. The ordinary parboiled and the parboiled (converted) samples of rice retained essentially the same quantity of vitamin B_1 and were similar in other characteristics when milled to the same degree.

All parboiling treatments improved the cooking quality of all three varieties, and the josh treatment improved the Caloro and Blue Rose samples. For use in canned soups neither the raw nor the treated lots of Caloro or of Blue Rose were entirely satisfactory, but rice of some of the parboiled lots held its shape better than the raw rice. All parboiled lots of Rexoro were satisfactory for use in canned soups, that from parboiling treatment No. 6 being best in appearance.

REVIEW OF LITERATURE

Hooper (*7*)[2] reports that in Bengal, rice is prepared for the market by three methods, known as balam, atapa, and siddha. In the balam treatment, paddy (rough rice) is sprinkled with hot water, which inflates the grain, and when the paddy is dried the hulls are easily removed. In the atapa treatment, paddy is soaked in cold water for 24 hours and then dried in the sun (hence, the name "atapa," or sun-prepared). The dried paddy is then milled with a mortar and pestle, and in milling many of the grains are broken. In the siddha treatment, paddy is first soaked in water and then boiled, dried, and milled. In this treatment, rice from oversoaked paddy is dark-colored, that from overboiled paddy is coarse in appearance, and that from overdried paddy is of poor milling quality.

Charlton (*5, p. 1*) says—

> In Burma the practice of parboiling paddy is to some extent a localized one. It is only in Lower Burma that parboiling is an important industry. In Upper Burma, parboiling is almost unknown and therefore a short explanation of the process is essential.
>
> In the process of parboiling, paddy (unhusked rice grains) is steeped in water in tanks, usually of cement, for periods up to three or four days. The water is then run off and the paddy transferred to vertical iron cylinders or cauldrons through which one or more steam pipes are placed vertically, these pipes being pierced with small holes at intervals along their length within the cylinders. Steam is blown into the paddy until the husk slightly dehisces, the steaming operation being then regarded as complete. The paddy is then allowed to fall out of the cylinders by removing a large trap door at the bottom and is either spread on the ground to dry in the sun or is dried by mechanical means. When thoroughly dry, the paddy is milled in the usual way.

Among the objects of parboiling, Charlton (*5, pp. 2–3*) reports that—

> Coringee coolies who are large consumers state that after a meal of parboiled rice they can work throughout a whole shift of eight hours without a further meal. If white [milled] rice were substituted they could not do this. . . . It is certain that the milling losses are reduced by this process. Breakage is greatly diminished. Partly because of this reduced breakage, the profits to the miller are increased by parboiling.
>
> In Burma the last reason probably accounts for the great increase in the number of parboiling mills since 1917. Practically all the parboiled rice is exported. On the other hand, in India, particularly in Bengal, the preparation of parboiled rice is a home industry, the work being carried out by women in the villages and not in mills. In brief, whereas parboiling is an ancient practice usually carried out in the home in India, in Burma it quite recently became an industry, the markets being chiefly India and Ceylon.

Ishaq (*8, pp. 16–17*) reports:

> There is also another method of preparing rice for export. It is called *Josh* (boiling). The process is as follows:—First of all dirt is removed from paddy by passing it through sieve[s]. Big earthern pots are filled with paddy and water and kept on ground covered with a six-inch layer of rice husk as fuel. This is then lighted. For the whole night these jars remain there on the fire, next day the water is drained off and the paddy is subjected to a second heating in shallow iron pans kept on the fire. For an hour each jar is heated and [the paddy is] then taken out and spread on roofs for drying. The first boiling [soaking] is sometimes done in iron tubes instead of earthen jars. In their [this] case, water is first heated to the boiling point and then the fire is removed and clean paddy is put in them and allowed to remain there for 8 hours. Then water is drained off and the stuff [rice] heated on pans and then dried as described above. Being semi-cooked, the husk easily separates in the mill and there is no breakage of

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[2] Numbers in parentheses refer to Literature Cited, p. 15.

grains. Besides, it is claimed that such rice has better keeping qualities and does not deteriorate when carried on long sea voyages.

Sethi and others (*15, pp. 714–715*) state that—

> Parboiling of paddy, a treatment preliminary to milling proper, is a general practice in the United Provinces in common with other provinces of India and many other parts of the world, such as Burma, Ceylon, Malaya and British Guiana. Besides the usual method of parboiling, another method of treating paddy is followed in the western United Provinces, chiefly in the Saharanpur District. It is known as *sela*-making, the treated milled rice being called "sela" to distinguish it from the rice milled raw (*i. e. kachcha* rice). Although essentially a method of parboiling, *sela*-making may be treated as a method by itself because of its fundamental difference from the method of parboiling usually practiced. The product obtained by this method, *i. e.* the *sela* rice, is superior in certain important respects to parboiled and kachcha rices. That this is so, is substantiated by the fact that *sela* rice is in demand in Burma, Bengal, Bihar and Orissa, although these provinces mill large quantities of parboiled rices of their own.
>
> Just as parboiled paddy has been termed steam-boiled or water-boiled paddy, *sela* paddy has been called lightly roasted paddy, although the word roasted is likely to over-emphasize the idea of gently heating the paddy, for that is what is actually done. The heating is done by means of hot sand. To begin with paddy is first steeped in fresh water in tanks for twenty-four hours to forty-eight hours. It is then taken out and gently roasted in hot sand contained in an iron pan heated by means of a *bhatti* (small furnace) fed by paddy husk. The paddy is briskly stirred along with the sand by means of an iron ladle provided with a wooden handle. . . . Experience is needed for judging the correct temperature of the sand and the correct duration for which the paddy should be allowed to remain in the sand. The heat should be just enough to evaporate the moisture from the wet paddy, instead of parching the rice. . . . The paddy is then further dried in the sun for two days and then milled in power hullers.

Lord (*14, p. 3*) says:

> Parboiling is universal in Ceylon, raw rice being used only for preparing a dish known as *Kiri-bat* and for turning into rice flour. This may account for the fact that, contrary to Charlton's experience in Burma, the Ceylonese find parboiled rice easier to cook than raw rice.

Codd and Peterkin (*6, pp. 23–24*) state that—

> The practice of parboiling the grain before milling is almost universal throughout the colony. The general procedure is as follows: The padi is first soaked in a tank of warm water at about 100° F. Light grains float to the surface and may be skimmed off. After the padi has been allowed to soak for about 24 hours, the water is run off and steam is injected at 30 to 50 lbs. pressure for 12 to 15 minutes. The padi is next spread in the sun for 12 to 15 hours to dry, and is then ready for milling.

The surplus rice produced in Kedah, Province Wellesley, and Krian is milled in power mills and, according to Jack (*9, p. 3*):

> Almost the entire output of rice from these mills is in the form known locally as "parboiled," that is, it is partially boiled usually by steam heat under pressure, before being milled. . . . The padi is heated for about 10 minutes in metal cylinders by steam under pressure (about 20 pounds per square inch) and then delivered into sacks which are conveyed to the drying floor. The parboiled padi must be thoroughly dried, as quickly as possible, before it can be milled.

These statements clearly show that parboiling and other related premilling treatments designed to improve the milling, keeping, and nutritional qualities of rice are not recent developments. For in parts of India, at least, rice consumers have long been aware of the need for a more nutritious milled rice. This need was recognized long before vitamins were isolated and their importance in human nutrition was established. Among people living on a restricted diet, consisting largely of milled raw rice, beriberi is common, whereas the disease is much less common where parboiled rice is substituted for raw rice in the diet. For example, in 1907, Braddon (*3, p. 156*), in discussing the prevalence of beriberi among Chinese and Tamil immigrants in Malaya, stated that "*Among the Chinese—the users of uncured (raw) rice—beri-beri is everywhere prevalent, whereas the Tamils—users of cured (parboiled) rice—are everywhere and always completely exempt.*" The reason for this difference in the nutritional value of raw and parboiled rice was not known until many years later, when milled parboiled rice, as compared with milled raw rice, was found to be rich in the antineuritic vitamin B_1.

In summarizing his work, Aykroyd (*1, p. 192*) says:

> Highly milled parboiled rice was found to be rich in the antineuritic vitamin B_1, while roughly [under] milled raw rice was deficient. . . . Exact comparison was made of the vitamin B_1 potency of two samples of rice, the one raw, the other parboiled, after similar degrees of milling. The vitamin value of the unmilled samples was equal, but when each was highly milled to an equal degree, as judged by weight of polishings removed in a hand rice mill, the parboiled sample retained the vitamin while the raw sample did not. . . . It is probable that when rice is steamed in the process of parboiling, the vitamin B_1 . . . contained in the germ and pericarp diffuse through the endosperm.

The siddha, sela, and josh treatments are apparently variations of the parboiling process, in which the soaked rough rice is steamed but not under pressure. Likewise, "rice conversion" is a modified method of parboiling, in which the soaking period is effectively shortened by evacuating the air from rough rice in a chamber and then soaking under pressure, followed by steaming under pressure.

During the war practically all the converted rice produced by the rice-conversion plant in Texas was purchased by the United States Government for the armed forces. A new rice-conversion plant, of larger capacity, was constructed in Texas by the Office of Defense Plants. This plant has been leased from the Office of Defense Plants by the processing company.

MATERIAL AND METHODS

Rough rice of the Caloro, Blue Rose, and Rexoro varieties, grown in 1943 under like conditions at Texas Substation No. 4, at Beaumont, was used in this study. Caloro is the most important commercial short-grain variety grown in California, and Blue Rose and Rexoro are the most important commercial medium- and long-grain varieties grown in the Southern States. The Caloro lot was overripe, contained considerable "pecky rice," and was of rather low milling quality, whereas the Blue Rose and Rexoro lots were of good milling quality, although the Rexoro was slightly immature. Rice grain from which a portion of the contents has been extracted in the dough stage by stinkbugs, leaving a chalky, discolored area, is known as pecky rice.

Rough rice of the three varieties was received at Beltsville, Md., early in the winter of 1943–44 and was stored under like conditions at room temperature until the samples were prepared for treatment. The treatments were applied in a laboratory in June and July 1944, or from 7 to 9 months after harvest. The sample of each variety was thoroughly mixed and aspirated twice before the subsamples were weighed for treating.

The individual samples, each weighing 600 gm., were soaked in 1,200 ml. of water in glass or enamel containers for the length of time and at the temperature desired. The treatments were as follows:

Treatment No.	*Name*	*Method of treating samples*
1	Check	Put in cold storage on July 1, 1944, and kept there until treatments were completed.
2	Atapa	Soaked in water at room temperature for 24 hours.
3	Siddha	Soaked in water at room temperature for 24 hours, then boiled for 7 minutes, and drained.
4	Sela	Soaked in water at room temperature for 40 hours, and steamed in heated quartz sand at a temperature of about 90° C. for 5 minutes. Rice and sand mixture vigorously stirred in an enamel container during steaming over a low gas flame.
5	Josh	Boiled in water for 2½ minutes, allowed to soak 7 hours. During this time the temperature of the water decreased from the boiling point to 36° C. Rice then drained, and steamed in an enamel container for 30 minutes over a gas flame. Rice stirred continuously during steaming.
6	Parboiled	Soaked in water at 60° C. for 16 hours, drained, and steamed at 15 pounds' pressure for 15 minutes.
7	do	Soaked in water at 70° C. for 16 hours, drained, and steamed at 15 pounds' pressure for 15 minutes.
8	do	Soaked in water at 96° C. for 2½ minutes, drained, and steamed at 15 pounds' pressure for 15 minutes.
9	do	Soaked in water at 80° C. for 3 hours, drained and steamed at 15 pounds' pressure for 15 minutes.
10	Parboiled (converted)	Placed in warm pressure cooker, evacuated 5 minutes, steam pressure raised to 10 pounds, then decreased to 2½ pounds, steaming repeated in this manner eight times, and cooker then evacuated for 5 minutes.
11	do	Placed in warm pressure cooker, evacuated 5 minutes, warm water (55°–60° C.) siphoned into pressure cooker, soaked under air pressure of 38 to 40 pounds for 2½ hours, drained, vacuumed 5 minutes, steamed at 11 to 12 pounds' pressure for 15 minutes, and again evacuated 5 minutes.
12	Parboiled (converted, plus vitamin B_1)	Same as No. 11, except 2,880 μg. of thiamine hydrochloride added to the soaking water.
13	Parboiled (plus vitamin B_1)	Same as No. 6, except 2,880 μg. of thiamine hydrochloride added to the soaking water.

A small pressure cooker equipped with vacuum, air, and steam pressure systems was used in evacuating and soaking parboiled (converted) treatments Nos. 11 and 12 under pressure and for steaming all parboiled lots. After each treatment the rice was spread out to dry at room temperature on a laboratory table, and electric fans were used to hasten drying. The treated samples were stirred occasionally during the drying, and, when dry, each sample was placed in an open-end envelope. Thereafter all samples were stored together under like conditions.

MILLING QUALITY

In order to determine the effect of treatment on milling quality, duplicate 50-gram samples of the raw and treated lots were milled in a small Menghetti mill of the pearling-cone type. This mill consists of an emery-coated cone that revolves at high speed within a perforated metal screen. The space between the cone and screen can be adjusted for milling rice of different types. Each lot was milled for 2½ minutes, and the yield of head rice (whole kernels) is shown in table 1.

Table 1.—*Milling quality of raw and pretreated rough rice*

Treatment No.	Name	Yield of head rice (average of two 50-gram samples)					
		Caloro		Blue Rose		Rexoro	
		Grams	*Percent*	*Grams*	*Percent*	*Grams*	*Percent*
1	Check (raw rice)	18. 5	37. 0	27. 9	55. 8	23. 5	47. 0
2	Atapa	. 5	1. 0	3. 9	7. 8	4. 7	9. 4
3	Siddha	20. 1	40. 2	27. 6	55. 2	29. 6	59. 3
4	Sela	22. 2	44. 4	[1] 19. 1	[1] 38. 2	27. 7	55. 4
5	Josh	24. 1	48. 2	28. 1	56. 2	28. 0	56. 0
6	Parboiled	31. 1	62. 2	32. 0	64. 0	29. 9	59. 8
7	do	31. 9	63. 8	31. 7	63. 4	31. 8	63. 6
8	do	14. 5	29. 0	28. 0	56. 0	29. 6	59. 2
9	do	28. 8	57. 6	29. 7	59. 4	29. 8	59. 6
10	Parboiled (converted)	19. 9	39. 8	28. 9	57. 8	30. 5	61. 0
11	do	31. 5	63. 0	28. 4	56. 8	31. 5	63. 0
12	Parboiled (converted, plus vitamin B_1).	30. 1	60. 2	31. 3	62. 6	30. 8	61. 6
13	Parboiled (plus vitamin B_1)	31. 1	62. 2	31. 1	62. 2	30. 0	60. 0

[1] Dried too fast—exposed to sunlight through window.

The atapa treatment resulted in excessive breakage in all varieties and hence was not assayed for vitamin B_1. Parboiled treatment No. 8 increased breakage in Caloro, had no effect on Blue Rose, and improved the milling quality of Rexoro. All other treatments materially increased the yield of head rice of each variety, except No. 4 with Blue Rose. The average increase in the yield of head rice for the siddha, sela, and josh treatments, as compared with raw rice, was 20 percent for Caloro and Rexoro. None of these treatments improved Blue Rose. The average increase for the eight parboiled treatments was 48 percent for Caloro; 8 percent for Blue Rose; and 30 percent for Rexoro. The average increase in head-rice yield for the three varieties was 8 percent for siddha, sela, and josh treatments, and 26 percent for the eight parboiled treatments.

Naturally, the extent of improvement in milling quality depends upon the milling quality of the rough rice treated. Rough rice of low milling quality is improved much more than rough rice of high milling quality.

MILLING BROWN RICE

For a study of the effect of treatments on the thiamine content of the rice, the hulls were removed from raw and treated samples by gently rubbing the grain between blocks of wood coated with corrugated rubber, and the brown rice obtained was then milled in a laboratory polisher or brush. The raw and treated samples were milled to three different degrees of intensity, viz, until the losses in weight were approximately 5, 10, and 15 percent of the weight of the brown rice, respectively. The samples reduced 5 percent in weight are designated as undermilled rice, those reduced 10 percent as milled, and those reduced 15 percent as highly milled. The parboiled-undermilled samples were more attractive in appearance than the raw-undermilled lots, indicating that it is not necessary to mill parboiled rice so closely as raw rice to obtain an equally attractive milled product. Thus, as compared with raw rice, the parboiled-milled rice sold in markets is usually undermilled.

Wise and Broomell (*16*) have shown that in modern milling, raw brown rice is reduced approximately 10 percent in weight by scouring off the bran layers, germ, and probably some of the endosperm. About 70 percent of the ash, 85 percent of the fat or oil, 70 percent of the crude fiber, 10 percent of the protein, and 30 percent of the pentosans are removed. Kik (*11*) reports that brown rice contains 3 to 5 μg. per gram of thiamine, 0.60 μg. per gram of riboflavin, and 60 μg. per gram of niacin, and that milling raw brown rice results in a loss of 80 percent of the thiamine, 50 percent of the riboflavin, and 65 percent of the niacin. These figures clearly indicate the deleterious effect of machine milling on the nutritive value of raw rice. Thus, means by which the loss of essential food elements may be reduced in the milling process are worthy of investigation, especially in countries in which rice is the staple food and in which the diet is not properly supplemented with protective foods possessing the essential elements in which milled rice is deficient.

THIAMINE (VITAMIN B_1) CONTENT

The thiamine content of the raw and treated rices, milled to different degrees, was determined by the thiochrome method. The average thiamine content of duplicate samples of each lot is shown in table 2.

TABLE 2.—*Thiamine content (in micrograms per gram of rice) of raw and pretreated milled rice*

[5 percent, undermilled; 10 percent, milled; and 15 percent, highly milled]

Treatment No.	Name	Degree of milling of brown rice (percent)[1]															
		Caloro				Blue Rose				Rexoro				Average, three varieties			
		None	5	10	15	None	5	10	15	None	5	10	15	None	5	10	15
1	Rough rice	2.46				2.20				2.15				2.27			
1	Brown rice (raw)	3.71	2.39	1.19	0.41	3.22	2.36	0.82	0.37	3.28	1.95	1.07	0.58	3.40	2.23	1.03	0.45
3	Siddha		3.10	2.79	2.71		2.76	2.33	2.25		2.59	2.59	2.38		2.82	2.57	2.45
4	Sela		3.11	2.72	2.47		2.24	1.84	1.71		2.51	1.96	1.82		2.62	2.17	2.00
5	Josh		2.43	2.34	2.30		2.43	2.23	2.07		2.10	1.85	1.93		2.32	2.14	2.10
6	Parboiled		2.20	2.30	2.26		2.26	2.22	2.14		2.14	2.10	2.00		2.20	2.21	2.13
7	do		1.87	1.92	1.88		2.00	1.75	1.90		1.99	1.88	1.87		1.95	1.85	1.88
8	do		2.05	1.78	1.71		1.89	1.83	1.60		2.11	2.05	1.82		2.02	1.89	1.71
9	do		2.36	2.47	2.56		2.53	2.39	2.24		2.27	2.29	2.14		2.39	2.38	2.31
10	Parboiled (converted)		1.89	1.97	1.76		1.98	1.74	1.68		1.77	1.74	1.51		1.88	1.82	1.65
11	do		2.36	2.35	2.17		2.01	1.93	1.76		1.76	1.77	1.85		2.04	2.02	1.81
12	Parboiled (converted, plus vitamin B_1)		2.56	2.63	2.57		2.46	2.35	2.32		2.54	2.38	2.20		2.52	2.45	2.36
13	Parboiled (plus vitamin B_1)		2.68	2.58	2.53		2.58	2.43	2.41		2.39	2.31	2.24		2.55	2.44	2.39

[1] Expressed in terms of percentage of weight lost.

The average thiamine content per gram of the raw rough rice of the three varieties was 2.27 μg., and of the raw brown rice, 3.40 μg. The latter figure is slightly lower than that of [raw] brown rice of the same varieties from the same source, reported by Cailleau and others (*4*) in analyses made 6 months after harvest.

In milling, the average loss of thiamine of the three varieties was for raw undermilled rice, 34 percent; milled rice, 70 percent; and highly milled rice, 87 percent. The average thiamine losses for the siddha, sela, and josh treatments for the undermilled, milled, and highly milled lots were 24, 33, and 36 percent, respectively. These losses are much less than for the raw rice and somewhat lower than for the more attractive parboiled rices, that is, treatments Nos. 6, 7, 9, and 11. The average thiamine loss for these latter samples—undermilled, milled, and highly milled—was 37, 38, and 40 percent, respectively, whereas in the less attractive parboiled rices—treatments Nos. 8 and 10—the average loss was for the undermilled samples, 43 percent; milled, 45 percent; and highly milled, 51 percent. The average thiamine loss for parboiled lots Nos. 12 and 13, to which a small quantity of thiamine hydrochloride (vitamin B_1) was added to the soaking water, was for the undermilled, milled, and highly milled rices, 25, 28, and 30 percent, respectively. The results were substantially alike for all varieties.

These results show that in all premilling treatments much of the vitamin B_1 of the brown rice had diffused into the endosperm of the grain. This diffusion was more complete in some treatments than in others. For example, in the parboiled lots Nos. 8 and 10, the treatments while beneficial were less effective in thiamine retention than were parboiling treatments Nos. 6, 7, 9, and 11. This was probably due to the fact that in treatment No. 8 the rough rice was not well soaked prior to steaming, and in treatment No. 10 the steam failed to penetrate effectively into the endosperm of the unsoaked rough rice. As a result, the treated kernels were translucent on the outer surface, but the inner parts of the endosperm were more or less opaque, indicating less penetration of thiamine.

The highly milled lots of the siddha, sela, and josh treatments retained 5 times as much vitamin B_1; parboiling treatments Nos. 6, 7, 9, and 11, 4.5 times as much; and parboiling treatments Nos. 8 and 10, 3.7 times as much vitamin B_1 as raw lots milled to the same degree. The relatively small losses of thiamine in the milled and highly milled treated rices, as compared with the raw rices, clearly indicate that the thiamine of the bran layers and germ had diffused into the endosperm of the treated rice.

The brown and milled rice of parboiled lots Nos. 6 and 13, and also parboiled (converted) lots Nos. 11 and 12, were essentially identical in appearance, in milling quality, and in thiamine content when milled to the same degree. In parboiled lots Nos. 6 and 13 the rough rice was soaked in water at a temperature of 60° C. for 16 hours before steaming, whereas parboiled (converted) lots Nos. 11 and 12 were soaked in water under pressure at temperature of 55° to 60° C. for 2½ hours before steaming. Therefore, as treated, soaking under pressure was no more effective in thiamine retention in the milled rice than soaking for a longer period without pressure. The loss of vitamin B_1 in all milled and highly milled treated samples was very small as compared with that of raw rice.

Parboiled lots Nos. 12 and 13, to which a small quantity of thiamine hydrochloride was added to the fresh water in which the rough rice was soaked, retained more vitamin B_1 in the undermilled, milled, and highly milled rices than other treated lots, except siddha. This indicates that by adding thiamine hydrochloride to water in which the rough rice is soaked, prior to steaming, the milled rice is somewhat improved in vitamin B_1 content.

These results agree with those reported by Aykroyd and others (*2*) for eight varieties of hand-pounded [undermilled] and machine-milled raw and parboiled rice. The average thiamine content of the raw brown rice for five of the varieties used by them was 2.9 μg. per gram; of the eight raw samples—for the hand-pounded, 2.4 μg. per gram, and for the machine-milled, 1.0 μg. per gram; for the parboiled hand-pounded, 2.4 μg. per gram; and for the parboiled machine-milled, 2.2 μg. per gram. Aykroyd and others (*2*) also determined the vitamin B_1 content of the bran removed from raw and parboiled rice of one variety milled for different durations. The raw and parboiled bran removed in 0 to 5 minutes contained 45 and 25 μg. per gram; in 5 to 10 minutes, 55 and 16 μg. per gram; in 10 to 15 minutes, 23 and 15 μg. per gram; and in 15 to 20 minutes, 11 and 11 μg. per gram, respectively. They conclude (*2, p. 28*) that—

> the outer layers removed in succession from raw rice are rich in vitamin B_1 [thiamine], the values falling off in the layers that lie more deeply. With parboiled rice, in contrast, the outermost layers contain much less vitamin B_1 and there is a less marked decrease in the value of the inner layers.

These investigators (*2, pp. 34–35*) also found that—

> the nicotinic acid [niacin] content of husked [brown] rice, i. e., rice which retains germ and pericarp almost intact, is 4 mg. to 5 mg. per cent [100 gm.]. Raw rice when pounded loses about half the nicotinic acid originally present and when machine-milled about two-thirds. This shows that most of the nicotinic acid in the rice grain is concentrated in the germ and pericarp. When rice is parboiled on the other hand, little nicotinic acid is lost on pounding and milling, indicating that nicotinic acid diffuses through the grain in the same way as vitamin B_1.

They confirmed this by determining the nicotinic acid content of some or all of the raw and parboiled hand-pounded and machine-milled varieties mentioned in the preceding paragraph. Four raw hand-pounded and four machine-milled varieties contained 2.4 and 1.6 mg., respectively, of nicotinic acid per 100 gm. of rice; whereas the four parboiled hand-pounded and eight machine-milled varieties contained 4.0 and 3.8 mg., respectively, of nicotinic acid per 100 gm. of rice.

Kik and Williams (*13*) in laboratory studies milled raw (unconverted) and parboiled (converted) rice to the same degree and determined the thiamine, riboflavin, and niacin content of the milled rice. The degree of milling was not indicated, but the 2 raw-milled samples retained an average of 0.68 μg. per gram of thiamine, and the 13 converted samples an average of 2.38 μg. per gram. This latter figure is almost identical with the thiamine retention of 2.30 μg. per gram in the 11 parboiled and related undermilled treatments here reported. Omitting lots Nos. 12 and 13, for 9 treatments the average was 2.25 μg. per gram. Thus, these laboratory results indicate that parboiled (converted) and well-parboiled milled rice retain essentially the same quantity of thiamine. The milled raw and parboiled (converted) samples reported by Kik and Williams (*13*) retained an average of 19.7 µg. and 41.8 µg. per gram of niacin, respectively. This confirms the findings of Aykroyd and others (*2*) with respect to the diffusion of niacin into the endosperm of parboiled rice.

Reuse of the soaking water might result in some enrichment of rough rice soaked in water containing thiamine dissolved from previous lots. This procedure and the degree of milling probably accounts for some of the variations noted in the thiamine content of different lots of parboiled and parboiled (converted) milled rice reported in the literature. For example, Cailleau and others (*4*) show a loss of 1.60 µg. per gram of thiamine and Kik (*11*) shows a loss of 1.76 µg. per gram in brown parboiled rice as compared with raw brown rice. Thus, on this basis, water used for soaking several lots of rough rice might contain as much or nearly as much thiamine per gram as raw rough rice, and, as indicated, soaking rough rice in such water might result in the retention of more thiamine in the rice milled from it.

There is no obvious reason, therefore, why the thiamine and niacin content of parboiled rice could not be increased by the addition of these vitamins to the water in which the rough rice is soaked. Kik (*12*) reported that 66 percent of the niacin content in [raw] brown rice was removed in the milling process, whereas in parboiled rice only about 20 percent was removed. The bran and polish were rich in niacin, indicating that the bran layers and germ are rich in niacin, as well as in vitamin B_1. This agrees with the findings of Aykroyd and others (*2*).

The reuse of soaking water would, of course, give a product variable in thiamine content, for the lots first soaked would be lower in thiamine content than those soaked in water that had previously been used. The results of treatments Nos. 12 and 13 suggest, however, that milled rice uniformly higher in thiamine content may be obtained by the addition of thiamine hydrochloride to the water in which the rough rice is soaked prior to steaming.

Even without enrichment, the results presented definitely show that parboiled, siddha, sela, and josh milled rices are of much better nutritional quality (vitamin B_1 content) than raw rice milled to the same degree. The better milling, keeping, and nutritional qualities of pretreated milled rice, as compared with raw rice, are factors worthy of serious consideration, especially in the large rice-producing and -consuming countries of Asia, in which rice is the "staff of life," and people live on a restricted diet.

COOKING AND CANNING QUALITY[3]

For observations on cooking and canning quality, raw and treated samples of milled rices were sent to a large soup manufacturer. The rice used was from lots milled 2½ minutes in a Menghetti mill. Each lot was cooked in boiling water for 18 minutes, and the cooked rice was put in cans in a 3-percent saline solution. The filling temperature of the solution was 170° F. The cans were held for 5 minutes after sealing and then processed at 15 pounds' steam pressure for 30 minutes, cooled immediately, and examined to determine the extent to which the rice maintained kernel identity or whether it became mushy or otherwise undesirable.

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[3] Through the courtesy of J. J. Spartales, chemist.

The boiled raw rice of each variety had a better appearance than the siddha and sela lots, but was less desirable in appearance than the josh and parboiled rice. Of the parboiled lots, Nos. 8 and 10, as previously indicated, were underparboiled and not quite so desirable in cooking quality as parboiled lots Nos. 6, 7, and 11. Thus, parboiling improved the cooking quality of all varieties.

Both the raw and treated samples of Caloro and Blue Rose were unsatisfactory for use in canned soup. Of the parboiled Caloro lots, however, the rice of treatments Nos. 7, 8, 10, and 11 retained its shape better after sterilization in cans than those of the raw rices; and of the parboiled Blue Rose lots, the rice of treatments Nos. 6, 7, and 11 also retained its shape better than the raw lots. All parboiled Rexoro rice samples were satisfactory for use in canned soup, and of the parboiled lots, rice of treatment No. 6 had the best appearance in the canned product.

Processing for 30 minutes in sealed cans was apparently much more harmful to the shape and appearance of the Caloro and Blue Rose varieties than to the long-grain Rexoro. The reason for this difference in reaction to processing (steam-pressure sterilization) after boiling is not clear. It may have been due largely to the difference in shape of the kernels or to a combination of shape and differences in the nature of the starchy endosperm of the varieties. In earlier experiments parboiled Rexoro and Fortuna rices proved to be satisfactory for use in canned soups, as reported by Jones and Taylor (*10*).

DISCUSSION

The laboratory studies here reported indicate that in order to produce a uniform product by parboiling, the rough rice should be (1) thoroughly soaked, (2) effectively steamed, and (3) properly dried. Rough rice when soaked absorbs warm or hot water more rapidly than cold. Thus, the soaking period, which apparently is the bottleneck in parboiling operations, can be effectively shortened by using warm or hot water and by soaking under pressure.

It is not possible to steam-soak rough rice uniformly in stationary metal cylinders. This is because soaked rice in contact either with the metal or with the steam pipes is often oversteamed; whereas, that more distant from the cylinders, or source of steam, is often understeamed. This results in a product uneven in appearance.

Some means of agitating or keeping the soaked rice in movement is necessary to assure uniform steaming. This is an engineering problem and probably not too difficult to solve. Steaming in a partly filled rotating drum or in a cylinder that rocks back and forth should give the desired effect.

Too rapid drying of rough parboiled rice, as for rough raw rice, is harmful to milling quality. Rice can be properly dried, however, in modern rice driers.

In areas in the United States where the rice crop is combined and the moisture content of the grain is relatively high, the rough rice might be parboiled (i. e., steamed) without soaking. A few years ago, C. Roy Adair [4] and the senior author stripped the grain from some Fortuna plants ripe enough for combining and steamed it in a pressure cooker. The steamed rice had the same appearance as soaked parboiled rice. Hence, it might be possible to combine part of the rice crop at a sufficiently high moisture content to permit steaming without soaking, following which artificial drying could proceed as for raw combined rice. This would eliminate the soaking and drying now done at the parboiling plant. The cost of steaming should be relatively low, and rice driers are now available in those areas where the crop is harvested with combines.

Parboiling and related treatments of rough rice prior to milling improve the milling, nutritional, cooking, and keeping qualities of milled rice and have long been used in parts of India and probably elsewhere. Despite the beneficial effects of such treatments on the quality of the milled rice, parboiled rice is apparently preferred and consumed primarily by the poorer peoples; whereas, many of the well-to-do and others eat the less nutritious raw-milled rice. Parboiling apparently is not practiced in China, Japan, Korea, or Formosa, nor in the Philippine Islands or the Netherlands East Indies, yet rice is the staple food for millions of people in these countries.

Parboiling changes the characteristics and appearance of milled rice, but when cooked by boiling, the kernels are essentially as white as raw rice and retain their shape better. The treatment, however, changes the flavor slightly, and to some consumers the resulting flavor is less desirable than that of raw rice. In countries with a low per capita consumption of rice and a varied diet the improved keeping and cooking qualities of parboiled rice should appeal to the housewife, for the modified flavor is dissipated after the usual preparatory methods or is masked by subsequent use in foods containing flavor substances.

In analyzing five typical diets in various parts of India, in which the daily intake of rice varied from 510 to 740 grams, Aykroyd and others (*2*), after assuming that half the vitamin B_1 present in milled rice is removed in washing and cooking, state that "then the minimum value which uncooked rice, forming the basis of diets of this nature, must have in order to obviate the danger of beriberi will lie between 1.4 and 1.7 micrograms/gramme." The eight varieties of hand-pounded raw rice, and all the hand-pounded and machine-milled parboiled samples, reported by Aykroyd and his associates, were above this minimum; whereas, all machine-milled raw rices had a vitamin B_1 content of less than 1.4 μg. per gram. The results here reported show that raw undermilled rice and all treated rices (undermilled, milled, and highly milled) were well above this minimum daily requirement.

The relatively high average thiamine content of all treated samples when milled to different degrees indicates that soaking and steaming result in a rather even distribution of thiamine in the grain. The change in structure of the grain, as judged by the milling quality, depends upon the manner in which the grain is steamed. For example, the parboiled treatments, in which the rice was steamed under pressure, resulted in greater change in grain structure than the sela and josh treatments, in which the rice was steamed without pressure.

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LITERATURE CITED

(1) AYKROYD, W. R.
1932. THE EFFECT OF PARBOILING AND MILLING ON THE ANTINEURITIC VITAMIN (B_1) AND PHOSPHATE CONTENT OF RICE. Jour. Hyg. [London] 32: 184–192.
(2) ——— KRISHNAN, B. G., PASSMORE, R., and SUNDARARAJAN, A. R.
1940. THE RICE PROBLEM IN INDIA. Indian Med. Res. Mem. 32: 1–84, illus. Calcutta [India].
(3) BRADDON, W. L.
1907. THE CAUSE AND PREVENTION OF BERI-BERI. 544 pp. London and New York.
(4) CAILLEAU, R., KIDDER, L. E., and MORGAN, A. F.
1945. THE THIAMINE CONTENT OF RAW AND PARBOILED RICES. Cereal Chem. 22: 50–60, illus.
(5) CHARLTON, J.
1923. THE PREVENTION OF NUISANCES CAUSED BY THE PARBOILING OF PADDY. Pusa Agr. Res. Inst. Bul. 146, 38 pp., illus.
(6) CODD, L. E. W., and PETERKIN, E. M.
1933. RICE IN BRITISH GUIANA, 1927–1932. PART I. VARIETAL AND INDUSTRIAL INVESTIGATIONS. Brit. Guiana Dept. Agr. Rice Bul. 1: 1–38, illus.
(7) HOOPER, D.
1909. THE COMPOSITION OF INDIAN RICE. Agr. Ledger 1908–09, No. 5 (Veg. Prod. Ser. No. 110), pp. 63–109. Calcutta.
(8) ISHAQ, A. R.
1921. RICE CULTIVATION IN THE LARKHANA DISTRICT, SIND. (A PRELIMINARY SURVEY.) Bombay Dept. Agr. Bul. (1920) 99, [34] pp., illus.
(9) JACK, H. W.
1923. RICE IN MALAYA. Fed. Malay States Dept. Agr. Bul. 35, 96 pp., illus.
(10) JONES, J. W., and TAYLOR, J. W.
1935. EFFECT OF PARBOILING ROUGH RICE ON MILLING QUALITY. U. S. Dept. Agr. Cir. 340, 15 pp., illus.
(11) KIK, M. C.
1943. VITAMIN RETENTION AND PROCESSING. Rice Jour. 46: 14–16.
(12) ———
1945. NICOTINIC ACID (NIACIN) IN RICE. Rice Jour. 48: 5, 18–20.
(13) ——— and WILLIAMS, R. R.
1945. THE NUTRITIONAL IMPROVEMENT OF WHITE RICE. Natl. Res. Council Bul. 112: 1–76, illus.
(14) LORD, L.
1928. RICE OUTTURNS OF PADDIES HUSKED FOR THE AGRICULTURAL CHEMIST. Trop. Agr. [Ceylon] 70: 207–210, illus.
(15) SETHI, R. L., SETHI, B. L., MEHTA, T. R., and GUPTA, P. S.
1937. OBSERVATIONS ON THE MILLING OF RICE IN THE UNITED PROVINCES. Indian Jour. Agr. Sci. 7: 713–732, illus.
(16) WISE, F. B., and BROOMELL, A. W.
1916. THE MILLING OF RICE AND ITS MECHANICAL AND CHEMICAL EFFECT UPON THE GRAIN. U. S. Dept. Agr. Bul. 330, 31 pp., illus.

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